DESIGN OF 5000 K. W. ISOLATED INDUSTRIAL POWER PLANT

BY

W. A. ALENDER

J. W. BARING

J. F. HILLOCK

ARMOUR INSTITUTE OF TECHNOLOGY

1 9 1 6

DESIGN OF 5000 K. W. ISOLATED INDUSTRIAL POWER PLANT

A THESIS

PRESENTED BY:

WALTER A. ALENDER

JOHN W. BARING

JAMES F. HILLOCK

TO THE

PRESIDENT AND FACULTY

OF

THE ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE

OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE IN

ELECTRICAL ENGINEERING

MAY, 1916.

Prof. of [illegible]

H M Raymond

PREFACE.

In the following thesis, the authors, for the sake of clearness, have adopted the method of proceedure as follows:

PART ONE- In which a general description of the problem of power plant design, including the location of the power plant, the steam equipment, and the electrical equipment, are given. Emphasis being placed on the latter.

PART TWO- A description of the particular problem as given out by the Engineering Society of Western Pennsylvania, in which the apparatus of this installation is described, and in addition to which, the problem is discussed from the economic standpoint.

TABLE OF CONTENTS.

PART ONE.

Introduction. In order that a clearer idea may be had concerning the problem given out by the Engineering Society of Western Pennsylvania, the authors have gone into a brief description of the general problem confronting the engineer in designing a power plant, such as the one above mentioned.

The problem of power plant design does not stop with the drawing of the plans for the station and equipment, but in addition, the problem of costs and expenditures of the plant itself, plus interest and depreciation charges on the investment, must be taken into account.

The engineer in working out his problem must make these costs a minimum, so that the gross yearly earnings of the plant, obtained from the sale of its product, may be as large as possible.

J.W.B.

W.A.A.

J.F.H.

GENERAL PROBLEM.

In designing a power plant, the engineer must first make himself entirely familiar with the conditions of the problem. The problem given out by the Engineering Society of Western Pennsylvania, gives a brief statement of the conditions upon which the design is to be conducted, including the conditions of the actual design, and the cost of the buildings and equipment, and operating expenses.

As a general thing, the exact location of the plant is essential, as it is best to determine the limitations on the actual construction work before going into the design of the building.

No matter where the plant is to be located, whether it is in the country, suburbs, or in the city, it is assumed that the output of the plant is marketable, and that the contracts for the sale of the current output, and in some cases, especially in the suburbs and in the cities, for the sake of steam and hot water for heating pur-

poses, have been drawn up and signed, otherwise it would be a poor business venture at the outset.

The selection of the power plant site would, in some cases, to a slight extent, be governed by the cost of the property. The cost of real estate varies as to the location, of course. In the country, this expense is light comparitively, to that one would expect to find in the suburbs or in the cities. In the latter case it is, of course, an important consideration and should be given serious thought. In the case of the problem given out by the Engineering Society of Western Pennsylvania, the location of the plant is on the harbor of New York City, and the cost of the land for the plant site was not considered in the problem, so that item did not enter into our calculations.

In cities and towns, the problem of local ordinances regarding the building and operation of power plants, necessitate consideration, and

sometimes seriously affects the entire design.

In all cases it is best to have the plant located as near as possible to some means of transportation, whether it is a railroad or water, it makes little or no difference, except perhaps in transportation rates. However, the facility with which a plant can obtain its coal and dispose of its ashes, is of the greatest importance, and adds or deducts from the plant efficiency, both in cost and operation.

In case of breakdown, rapid transportation of repair parts, or in some cases, entire units, is necessary, and involves a great loss if the plant has to shut down, which is, of course, very rare.

Close proximity to a fuel supplyis a consideration which sometimes reduces operating expenses, and guarantees the plant against a fuel shortage occasioned by labor troubles and other causes. In the city it is necessary for large plants, under contract to supply continuous service, to have a large supply on hand to carry

them over an emergency such as would be caused by troubles of this kind.

Ash handling is another feature of the preliminary design that must be taken into account. Means for the disposition of the ashes may be decided upon at the same time the fuel transportation problem is decided, as it is usually found expedient to run both ends by the same apparatus. If the plant is located in a large city, and close to large bodies of water, such as the oceans , Great Lakes, or navigable rivers, the coal and refuse can be dumped into the water, under certain conditions depending upon the local government restrictions.

Having covered the preliminary design as thoroughly as possible, the engineer can now start in on the actual desgn. It is, of course, understood that the location of the power plant, and local conditions, necessitate further investigation before attempting to start upon the actual design.

In starting the design it is first necessary

to draw up a load curve which will suit the conditions imposed in the problem, the total kilowatt hour consumption, and a maximum peak, being given. Load curves of one other power plant, similar in detail to the one to be designed, can be obtained, so that a general idea of the location of the peaks, can be determined. Taking this curve as an example, a load curve for the power plant under design can be drawn, and from this curve the value of the average load current is to be calculated.

The size and number of the units of the power plant is to be determined next, which of course depend upon the rated output of the plant, and the class of service to which the plant is to be subjected, taking into consideration that there must be a sufficient reserve capacity to permit continuous full load operation.

The total boiler horsepower necessary to run the plant at its full load capacity, was next determined. The boiler equipment was so designed that any number of boiler units could

operate at their maximum efficiency, a definite fraction of the load.

The choice of boilers can be made from either the horizontal or vertical, water tube or fire tube. Water tube boilers are safer than the fire tube boilers, and are less liable to get out of order. Water tube boilers are especially safe for high pressures. The boiler units are usually set in batteries of two each, with spacings of about five feet between batteries.

Automatic stokers are used in up-to-date plants, as their operation is much more efficient in every way, than the hand fired boilers. They economize on fuel, and require less attendance than is necessary for hand fired boilers.

There are various types of stokers on the market, and are generally divided into two classes: the under-feed and the over-feed types. The latter are again divided into the inclined, and the chain-grate stokers. In the under-feed, the coal is fed to the fire from underneath, usually by means of a screw conveyor. In the former, the coal is fed down from over-head

bunkers through down-spouts, upon a grate made up in the form of a chain. This grate is kept in continual motion , the ashes being removed from the rear of the furnace.

The over-head bunkers are fed by means of conveyors, from the main supply bunkers, into which the coal has been dumped from the cars or barges. Conveyors are usually of the continuous bucket type, being motor driven. They also can be used for removing the ashes, and are provided with mechanical trippers located at the place where the coal and ashes are to be dumped.

Condensers for turbines and steam engines are of the jet or surface type. In the jet type the steam is condensed by coming in contact with a spray of water, and in the surface type, the condensation takes place when the steam strikes the surface of pipes in which a circulation of cooling water is kept. Condensers of the surface type have the greater advantage, because the steam does not come in contact with the injection water, and hence it may be

used again.

The circulation water is pumped by means of a circulating pump, and the steam is removed by means of a "wet vacuum" pump, or when a high vacuum is desired, a "dry vacuum" pump is used in addition.

Feed water is supplied to the boiler by feed water pumps, this water must be free of impurities, or it will have to be specially treated before it can be used in the boilers. If the plant is located near a supply of fresh water, such as a river or a lake, the only difficulty usually experienced is in the removing of the sediment, especially where the water is "soft".

Feed-water heaters, into which the steam is exhausted, raise the temperature of the feed-water, so that a saving of roughly one per cent of the fuel for every eleven degrees the feed-water is raised in temperature, is accomplished.

All boiler s and equipment should be of highest efficiency, and no pains should be spared in making all apparatus as safe as modern engineer-

ing practice can make it.

The design of the electrical end of the power plant depends upon whether the plant is to supply alternating or direct current. Small isolated plants, such as those found in office buildings, where the length of the transmission is negligble, are as a rule direct current, supplied at normal voltages. Large plants , however, where the current must be transmitted for relatively long distances, alternating current at high voltages, is the usual practice.

The types of generator units depend largely upon the class of service.

In this particular problem, where the load variation was so great, the total load was divided so that it could be taken by a single unit, or by a number of units connected in series, depending upon the load requirements, and the machine or machines could be run at their maximum efficiency.

In selecting the voltages for the generator units, there are several conditions to be consider-

ed. If the voltage at which the power is to be distributed is less than 10,000, it is generally agreed that the ge nerators be of that voltage. However, if the voltage does not exceed 15,000, units can be purchased that will give this potential without the use of step-up transformers, but of course the saving in expense thus encountered, is often lost by the increased price of the generator units, due to the insulation for high voltage, and they are also more liable to injury due to lightning, than generators of a lower voltage.

Where transformers are used, the voltage is usually placed at 2200 as a minimum for small machines, while 6600 may be used for large units.

In order that the saving due to the generation of moderately high line voltages, without the use of transformers, may not be lost by the increased cost of high voltage generator units, the series system is sometimes used, especially where conditions require low voltage generators for separate loads.

Low voltages simplify, to a great extent, the cost and design of the switchboard and the auxiliary apparatus.

In the selection of generator units, the use of turbo-generators are a saving, not only in efficiency, but also in floor space, which sometimes is of the greatest importance. They also are about one-fifth the weight of a reciprocating unit and generator, this simplifies the floor construction, though it is best to have the generator units rest on piers, independent of the building so far as the floor strain is concerned.

Having selected the number of units and their size, the exciters for these units can be selected. As a rule the exciters are rated at 125-250 volts, compound wound, flat compounded. The exciters should be of such design that there will be no excessive rise in voltage due to a corresponding increase in speed. Whether or not the exciters are mounted upon the same mounting with the alternator, depends largely upon the size of the alternator. In late years, the practice of

mounting the exciters separately, has become quite universal, due to the increased size of the main units.

Exciters should be large enough to have ample reserve capacity, and in some cases storage batteries are used in connection with the machines for this purpose.

In selecting the switchboard, there are two types: the direct-control boards and the remote-control boards. Remote-control boards, however, for large plants, especially of high voltage, are becoming more generally used than the direct-control boards.

The remote-control boards are either of the vertical or the horizontal types, the horizontal type sometimes being called the bench board. In each of these forms of construction, the panels are conveniently grouped, and the actual connections to the generators or feeders are indicated on the panels by means of dummy or miniature bus-bars, and the main switches, whether open or closed, are indicated by means of signal lamps

placed near the controlling switch.

The instuments are located, in the case of the bench board, on a vertical panel above and in front of the board.

The selection of switches depends upon the voltage of the system. There are four general kinds to select from: Knife-blade, plug, brush contact with carbon break, and oil switches. Low tension work employ knife switches, while all high tension switching is done with oil switches, either electrically or pneumatically operated. All disconnecting switches for high tension work are knife switches, where they do not break the load current, but are placed between the apparatus and the source in series with other switches, so that the apparatus can be completely disconnected from the high tension circuit to enable repairs to be made.

Carbon break switches are called circuit-breaker switches, and are usually fitted with over-load, under-load, and reverse current breaking devices.

Relays for operating the shunt trip coils of circuit breakers, may be designed to open under the following conditions: No-voltage, over-voltage, over-load, and reversal of current. They may be instantaneous in operation, or with a fixed time limit, or an inverse time limit.

All power plants should have their electrical apparatus fully protected against damage due to excessive rise in voltage occasioned by lightning discharges.

The apparatus used for the protection must guard against excessive differences in potential between line and ground, line and line, and between conductor turns in such apparatus as transformers. Line apparatus consists of grounded overhead wires. Arresters are used in distributing systems for the protection of line transformers.

In localities where there is a pronounced tendency for electrical storms, great care should be taken in the selection of protective apparatus, both for the plant and for the

transmission lines, because of the damage that may be done to the station equipment.

There are various types of arresteгs, such as the choke coil types, the Westinghouse non-arcing arrester, the Garton arrester, Thomson's spark gap arrester, and the multipath and the multigap arresters.

High tension arresters are of the electrolytic cell type, as a rule, and for voltages above 13,500, the horn gap is used in addition.

....

The authors have, in this brief outline, attempted to give an idea of what the engineer must meet in attempting to design a modern steam power plant.

PART TWO.

Introduction- In preparing the description of the problem, considerable difficulties were experienced by the authors in obtaining cost data regarding apparatus and equipment used in the proposed installation.

Manufacturers of such apparatus and equipment are generally averse to giving prices of their products unless they are certain the applicant is in the market to buy.

Present conditions of the market, caused by foreign conditions, also make the estimates herein contained, rather conservative.

However, the authors are reasonably certain that all cost data are within 1% of the correct values.

J.W.B.
W.A.A.
J.F.H.

PARTICULAR PROBLEM.

The problem as given out by The Engineering Society of Western Pennsylvania, contains the necessary data upon which the design of the power plant is to be based.

STATEMENT OF PROBLEM.

A manufacturing concern is building a factory at the water's edge on New York harbor.

The plant will require power for operating motors running in size from 3 H.P. to 1000 H.P.

The plant operates from 7:00 o'clock Monday morning until 4:00 o'clock Saturday afternoon continuously.

The maximum power requirement will be 5000 kilowatts. The total kilowatt hours per year of the plant will be 14,000,000.

Electric power is purchasable in the form of 3-phase, 2200-volt, 60 cycle alternating current at the following rates:

A flat charge of $16.00 per year per kilowatt maximum demand plus a charge $\frac{3}{4}$ cent per kilowatt hour for the actual energy taken.

For the purpose of determining the method of suppling power to the plant it is necessary to ascertain the cost of power generated by an isolated plant to be installed by the manufacturing company. The conditions affecting the cost of generating power are as follows:

Coal of 14,000 B.t.u. heating value per pound can be delivered at the plant for $3.00 per ton.

Wages in the power plant will have to be as follows:

Chief Engineer..............$3000 per year.

Engineer in charge of each shift........... 1500 per year.

Firemen, each................1200 per year.

Oilers and water tenders, each............. 900 per year.

Common labor............20 cents per hour.

Buildings and foundations will cost:

For the engine and generator room.......... $5.00 per sq. ft.

For the boiler room......$4.00 per sq. ft.

Interest, insurance, taxes, maintenance and amortization taken collectively must be allowed for as follows:

On buildings and foundations.............8%

On apparatus and equiptment.............15%

Design and estimate the cost of and the cost of operation of a power plant to furnish the required power, and give the total annual cost of the power produced by the power plant, and of the purchased power.

The plant must have sufficient reserve capacity to permit full load operation continuously.

A lighting load of 250 kilowatts on Saturday and Sunday nights must be provided for.

<u>POWER STATION BUILDINGS AND EQUIPMENT</u>.

In the design of an isolated plant of this type, the engineer's problem resolves itself mainly into a problem of finance. Whether it is more economical to buy power, or whether it is more economical to generate power in an isolated plant.

With this idea in view special attention has been given to the selection of units, the

spacing of same, etc.

The power plant building is two stories in height, with a basement. It is made of pressed brick, with a concrete foundation, supported on cassions which rest on bed rock.

The basement of the building is fourteen feet deep, and contains all auxi liaries to the main units, conveyor, ash and fine coal hoppers.

Above the basement and above the level of the ground, is the floor of the turbine and boiler rooms.

The turbine room contains the gallery upon which the switchboard is located, and the engineer's office.

The roof is supported by compound Fink trusses, the turbine room roof has a skylight built into it.

Turbine foundations consist of concrete piers supported on cassions sunk to bed rock.

The intake and discharge flumes for condensing equiptment are tunnels 3 feet in diameter,

the intake being protected at the entrance by proper screens to exclude foreign matter.

The boiler room contains one row of boilers with four batteries to the row, and two boilers to the battery.Each boiler has an individual chain grate mechanical stoker, built by the Green Engineering Company, which is driven by a 10 H. P. squirrel cage induction motor, running a common line shaft.

Three of the batteries contain two 400 H.P. Babcock and Wilcox water tube boilers, The fourth being composed of two 300 H. P. boilers of the same make.

Boilers operate under 200 pounds pressure, and 150 degrees superheat.

Coal is fed to each boiler through a flexible chute from overhead bunkers.

The overhead bunkers, which are entirely of sheet steel supported on "I" beams, are filled by the conveyor which passes over them.

Coal is received from cars on the railroad siding, and is dumped directly from the cars into

the coal pit from which it slides into the coal crusher. From the coal crusher it is fed to the conveyor.

Ashes and fine coal from the boilers are fed to the conveyor and pass up over the the coal bunkers to the ash hopper situated above and directly over the the railway siding. From here the ahes may be dropped directly into the cars below.

A chute is provided by means of which ashes may be loaded on a barge. The down spout of the ash hopper is moved around by means of a rope and pulley, so that it may be directed into the ash chute on the barge.

The two stacks and breeching are located behind the boilers and between them and the turbine room wall.

The feed water heater and the boiler feed pumps and makeup pumps are located between the two stacks.

The feed water heater is a 1000 H.P. Stillwell open heater. It is so connected that in case of necessity the heater may be by-passed

and the exhaust from the turbines may be directed into the atmospheric exhaust line.

Feed water for the boilers is pumped by three 55 gallon Worthington centrifugal pumps which are turbine driven. The pumps all discharge into a main feed water header from which two hot lines are taken. One line to the boilers is situated above the boilers and is controlled from the floor by long handled valves, the other being underneath the boilers. Any two of the feed water pumps are capable of carrying the boiler load.

The boiler feed lines are so interconnected that they may be converted into cold water lines in case it becomes necessary to feed cold water to the boilers.

The varying conditions which a plant of this type is found to meet, makes flexibility an asset to the installation. During the course of the average working day, the load to be carried may vary from very little to full load, or even to a large overload. For this reason it was considered best to divide the generating units up into such a number as would best meet

these requirements.

The generating equipment was selected as follows:

Three 1000 Kilowatt G. E. 440-volt, 25-cycle 3-phase alternators, with Curtis turbines, directly connected by means of a shaft.

One 750 kilowatt G. E. 440-volt, 25-cycle, 3-phase alternator, with Curtis turbine.

The turbine units are all of the bleeder type, the steam being extracted from a stage when the pressure is above atmospheric.

The steam from the bleeder turbines is used for heating purposes, and during such times when the 250 Kilowatt unit is running alone, carrying the lighting load only, if the steam from the bleeders is not sufficient in amount, live steam from the boilers may be taken through a reducing valve.

All turbine units operate condensing and exhaust into a 1000 kilowatt Wheeler surface condenser, which has its circulating, hot-well, and dry vacuum pumps all situated on a common

base, and driven by a common turbine, directly beneath the condenser.

The exhaust line from each turbine is equipped with an atmospheric relief valve so that in case a pressure is maintained in the condenser, this valve will open automatically and allow the turbine to exhaust directly into the atmosphere.

Cooling water for condensers is taken from a main intake tunnel, which serves all the units and is discharged into a common discharge flume, both of which have their openings in the harbor.

The excitation is furnished from two 35 kilowatt compound wound G. E. generators, one being driven by an induction motor, and the other being turbine driven, and either one being capable of carrying the full excitation load.

The exciters are capable of being operated in parallel and are equalized on the negative side, the equalizing switches and connections being carried to the switchboard.

The turbine room floor is on the same level

as the boiler room floor, the two being connected by several doors.

The turbine room is of the metal skeleton type, permitting a plain view, from the floor, of the operation of the auxi liaries and apparatus in the basement below.

Above the turbine room floor is a crane, so situated that it may be made to carry any part of the equiptment on the floor down to the railway siding, which enters directly at the end of the building. The crane is of 50 ton capacity, and manually operated.

The switchboard, which is entirely inclosed on a gallery above the turbine floor, is of the upright type.

It consists of six generator panels, four feeder panels, two excitation panels, and an induction motor panel. Each generator panel has mounted on it, one polyphase indicating wattmeter, one voltmeter with potential receptacle for inserting voltmeter across each phase, one ammeter with switch for connecting ammeter into

each line, and one direct current ammeter for the field excitation.

The field switch is a knife switch with an auxiliary contact on it for short circuiting the field through a resistance when the switch is opened.

The field rheostat is mounted on the back of the board, and is controlled by means of a hand wheel mounted on the board.

The main generator switch is a G. E. type K-5, non-automatic hand operated oil switch.

Each generator panel contains a synchronizing receptacle, the synchroscope being located at the end of the board on a swinging bracket along with a direct current field voltmeter.

The four feeder panels each have mounted on them, one polyphase indicating wattmeter.

The main feeder switch is a G. E. type K-5 automatic oil switch, and the feeder is protected by an inverse time limit overload relay.

The exciter panels each have one direct

current ammeter on them, and a four point potential receptacle to the direct current voltmeter on the swinging bracket.

The main switch is a triple pole , single-throw, knife switch, the middle pole being the equalizing connection.

The induction motor panel contains one alternating current ammeter and a G. E. type K-5 automatic oil switch, protected by an inverse time limit overload relay.

COST OF APPARATUS AND EQUIPMENT.

(1) Buildings and Foundations.

Boiler Room 56 ft. x 141 ft. 7894 sq. ft. @ $4.00	31,576.00
Turbine Room 27,5 ft. x 141 ft. 3878 sq. ft. @ $5.00	19,387.50
Turbine Foundations,	3,100.00
Yard Work, including, Intake and discharge flumes for condensing water, grading, fencing and side-walks,	8,750.00
Coal Bunkers	8,500.00
Boilers, including, Settings and brick work,	57,500.00
Stokers, including, Driving mechanism, etc.,	9,250.00
Pumps, including, Boiler feed and make-up water,	2,000.00
Feed Water Heater and Oil Separator,	1,500.00
Stacks and Breeching,	12,000.00
Superheaters,	9,000.00
Piping , including, Pipe fittings, traps, separators, pipe coverings and pipe supports,	20,000.00
Conveyor,	12,500.00
Exciters,	3,500.00
Surface Condensors, including, Auxiliaries,	35,000.00

Turbo-Generators,	140,000.00
Oiling System,	1,000.00
Crane,	2,500.00
Switch-Board,	20,000.00
Wiring, for lights, motors, etc.,	1,250.00
Indicating and recording instruments, damper regulators, ladders, runways, and painting for boiler-room,	3,750.00
Total,	$407,063.50

COST OF POWER.

Assuming that the plant operates at full capacity at all times during the 6732 working hours, there would be an energy production of 33,660,000 kilowatt hours per year.

However, a load curve having its peak at 5000 kilowatts, and having a total energy output of 14,000,000 kilowatt hours, would show an average load of approximately 2000 kilowatts, exclusive of lighting load, to be carried on Saturday and Sunday nights.

This means operation of two generator

units, and the use of approximately 1200 boiler horse power, or three of the 400 horse power boiler units.

Working on this as a basis, the follow- is considered as sufficient labor to maintain operation of the plant per shift of eight hours.

Three common laborers, to keep bunkers filled, handle ashes, etc.,

Two firemen.

One water tender.

One oiler.

YEARLY OPERATING CHARGES.

Cost of labor per year for three 8-hour shifts composed of the following men:

Chief Engineer	$3000.00
Engineer in charge of each shift	4500.00
Two firemen	7200.00
One water tender	2700.00
Three common laborers	4039.20
Total,	$24,139.20

The coal used has a calorific value of 14,000 B. t. u. per pound, and costs $3.60 a ton delivered at the plant.

The 1000 kilowatt turbines consume, at 200 pounds pressure and 150 degrees superheat, 17.5 pounds of steam per kilowatt hour.

Steam at 200 pounds pressure and 150 degrees superheat, contains 1295 B. t. u. per pound.

B. t. u. consumed per kilowatt hour,	27,700
Pounds of coal consumed per kilowatt hour, assuming 60% grate and boiler efficiency	2.8
Cost of coal consumed per year	$56,600.00
Cost of oil and waste used per year	1,200.00

FIXED CHARGES.

Interest, insurance, taxes, maintenance, and amortization are allowed for as follows:

On buildings and foundations,	8%
On apparatus and equiptment,	15%
Fixed charges	$77,267.50
Total cost per year to produce 14,000,000 kilowatt hours	$159,206.70
Cost per kilowatt hour	.0113

Power may be purchased at the following rates:

A flat charge of $16.00 per kilowatt per year maximum demand, plus a charge of $\frac{3}{4}$ cents per kilowatt hour for energy actually taken.

Cost of energy under these conditions will amount to $. 013.

From the foregoing statements it may be seen that there would be an annual saving of $23,800, if power was generated in an isolated plant.

Under these conditions, allowing for interest, depreciation, taxes, etc., the original cost of installation would be saved in 17 years.

The figures given here regarding the cost of power apply to generation only, and does not consider the propostion of bleeding turbines and using steam for heating purposes. If this idea is considered, the cost of purchased power is increased appreciably by the necessity of installing the required heating apparatus.

However, since the amount of steam necessary for heating is not known, the difference in cost cannot be determined.

BIBLIOGRAPHY.

"Standard Handbook for Electrical Engineers"

"Handbook of Cost Data"...............Gillette.

"Proceedings and Transactions of the A.I.E.E. for the Year of 1912"

"Proceedings of the Engineering Society of Western Pennsylvania for the Year of 1913"

"Handbook of Cost Data"..............Pender .

"Cost Data and Estimates".............Burton.

"Steam Power Plant Engineering".....Gebhardt.

"Power Plant Engineering"..........Weingreen.

General Electric Bulletins and Catalogs

"Distribution of Maintenance and Operation

"Costs in Power Plants"..........H. G. Stott.

Isolated Power Plants Magazine for the months of June and July 1915.